

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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# PLC Course

مقرر الحاكومات المنطقية البرمجة

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## Lec 3

# **Relay Logic Ladder Diagram and PLC Ladder Diagram**

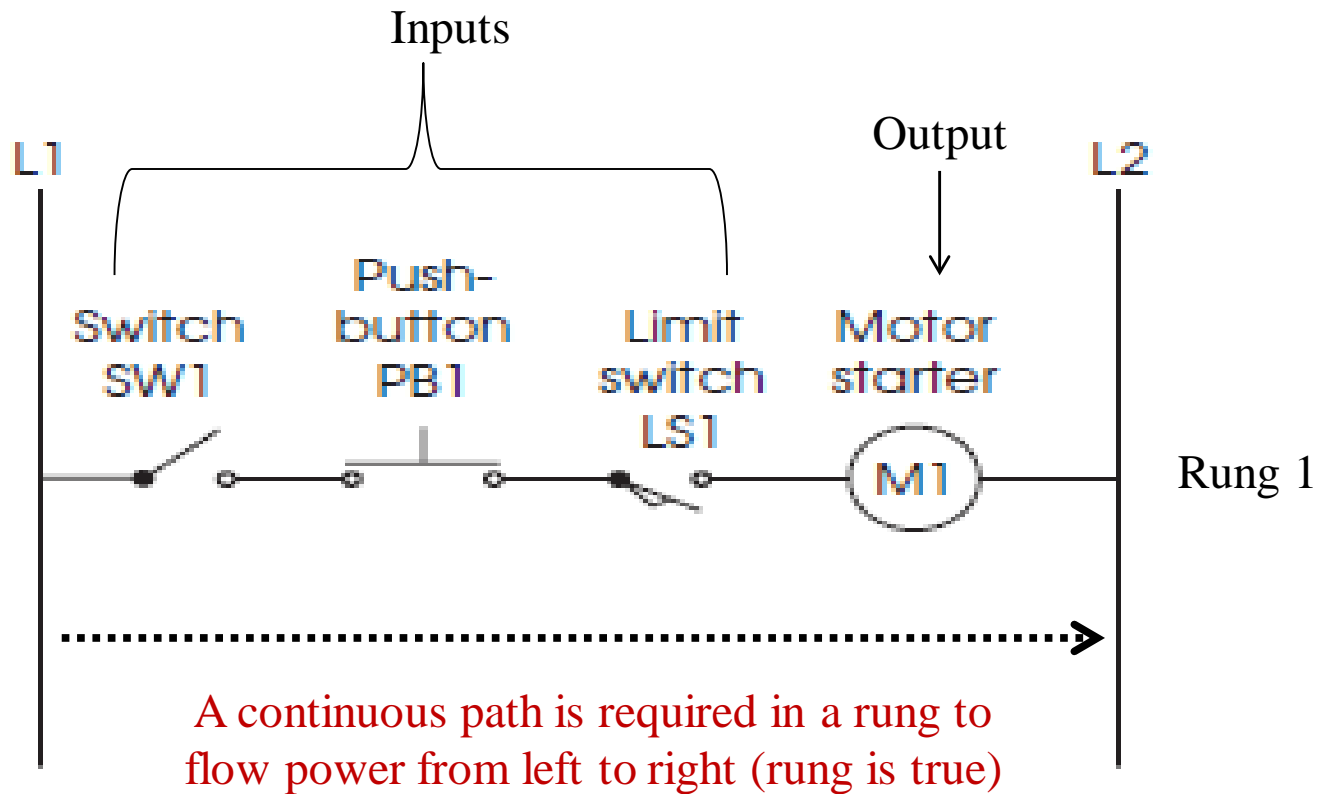
# (1) Relay Logic Ladder Diagram

## (Hard wired Ladder Diagram)

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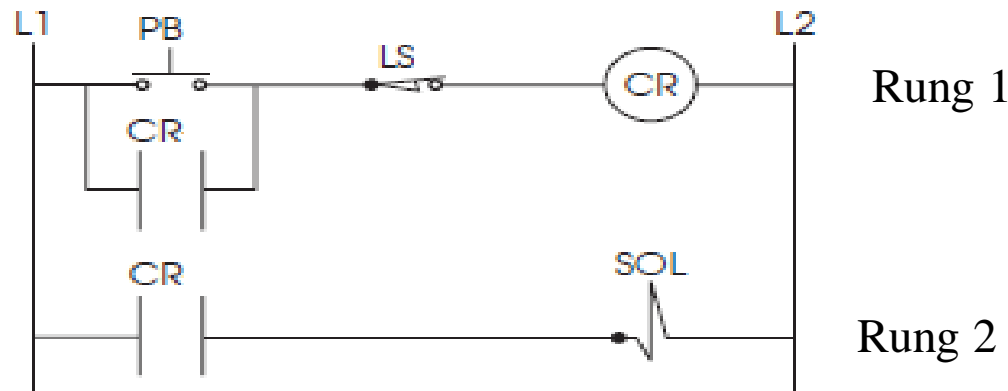
- Like ladder diagram, shows the logical relationship between I/O devices ([shows how to control outputs based on input conditions](#)).
- Certain symbols were used to represent different input and output devices.
- It also called [hardwired ladder diagram](#) or [relay logic diagram](#).
- The PLC power supply will be the voltage between the two [vertical lines](#), labeled **L1** and **L2**. In general, L1 represents the supply terminal and L2 represents the common (neutral) terminal.
- Relay logic diagrams [use rungs \(one or more\)](#) to accomplish the control of outputs based on input conditions.
- [power flows through any rung from left to right such that there exist a continuous path](#) (**logic continuity = rung is true**) [through this rung](#).

- Current in the below relay logic diagram can flow to the electric motor or motor starter (Turn ON the Motor) when all three input devices are closed.

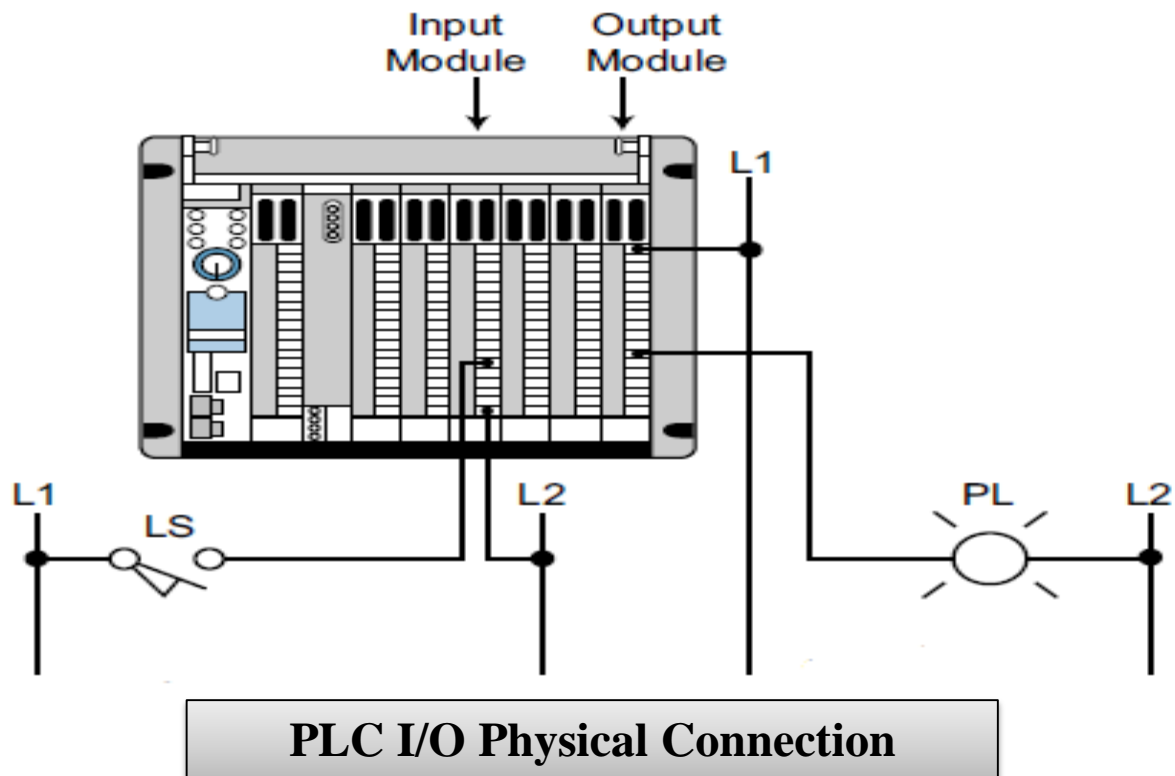
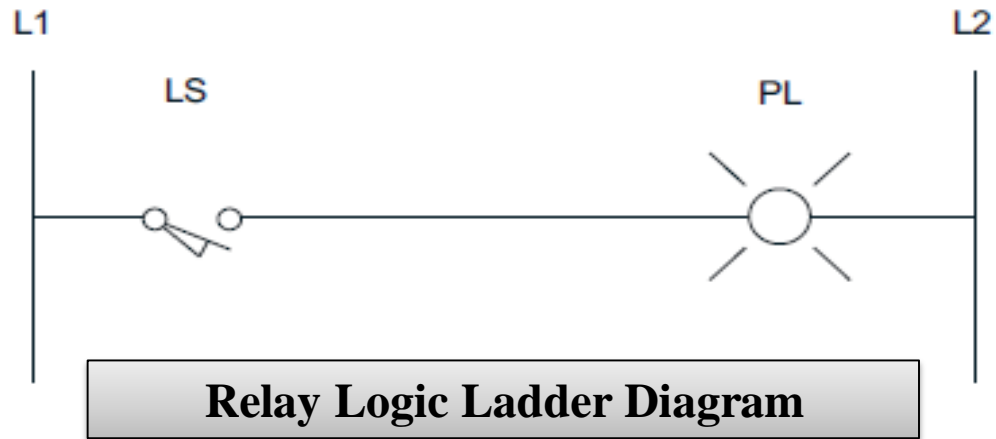


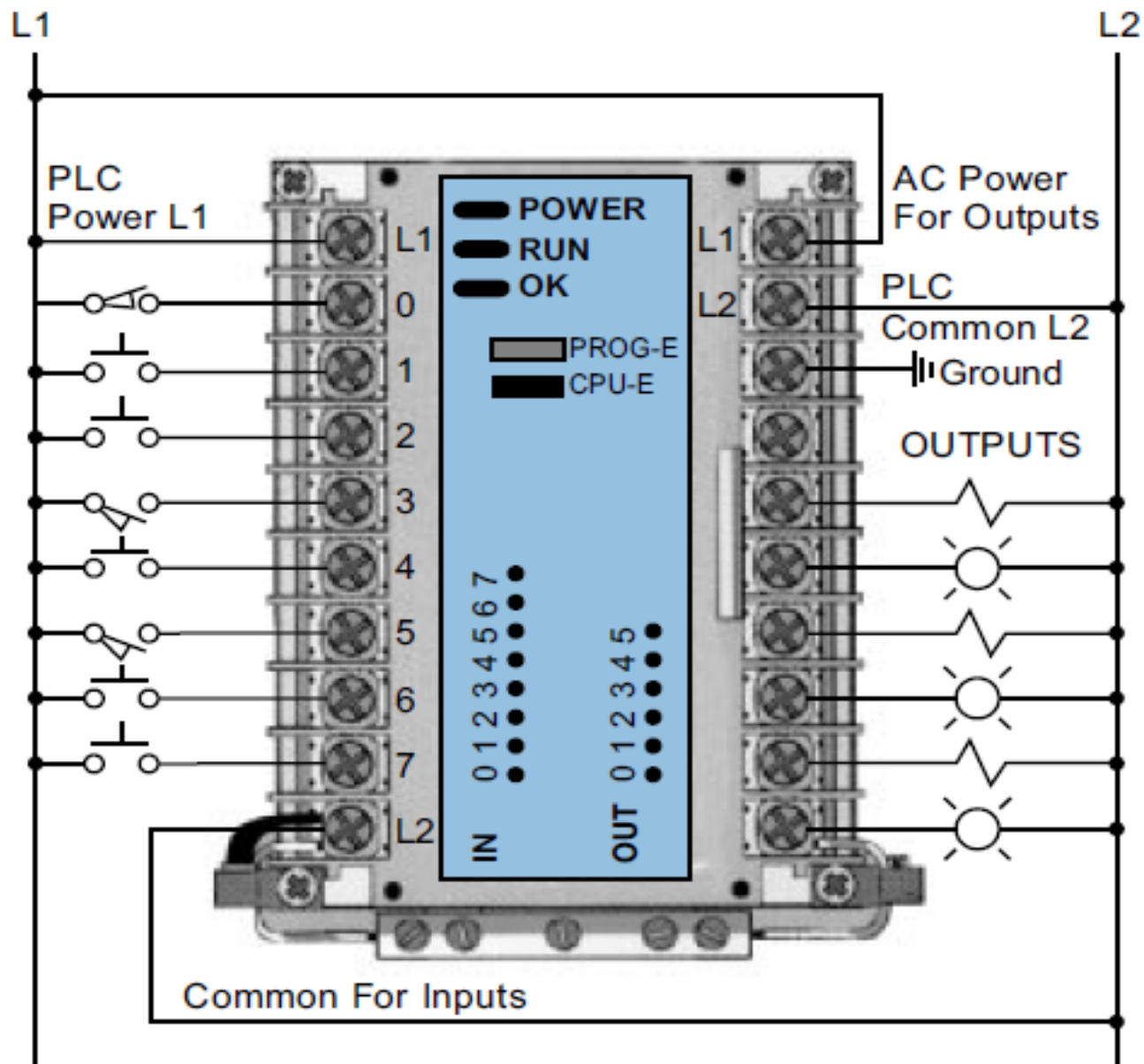
**Simple Relay Logic Ladder diagram**

- The following figure illustrates how a *relay coil* and *contacts* are used in a relay ladder logic diagram to control a solenoid.
- When pushbutton (PB) is pressed, the relay coil (CR) is energized and causes contact CR to close. Closed CR causes the solenoid to be energized. When the normally closed (NC) limit switch (LS1) is opened, the relay coil is turned off, and contact CR is opened. Opening the CR contact disables the solenoid (SOL).



**Use of a relay coil and contact in  
the Relay Logic Ladder diagram**



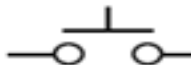














PLC I/O Physical Connection



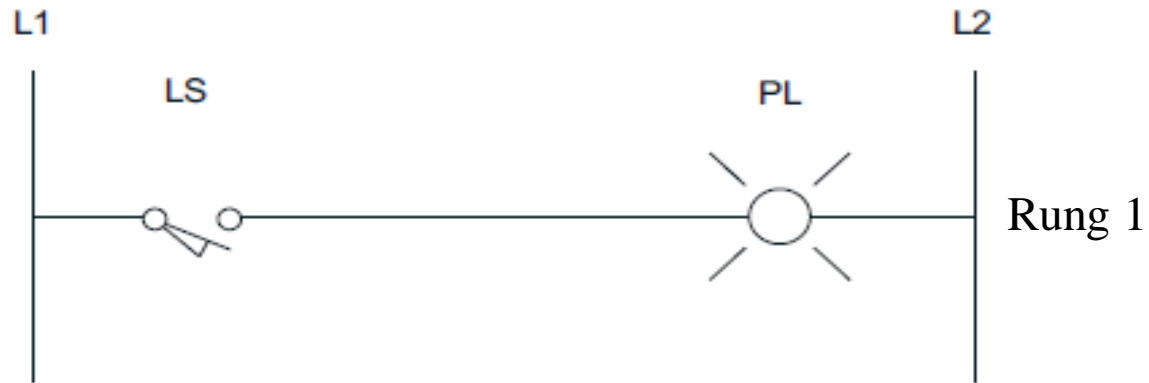
# Symbols used in Relay Logic Ladder Diagram

| Inputs                   |  | Outputs               |   |
|--------------------------|--|-----------------------|---|
| The input device         | Symbol   | The output device     | Symbol  |
| Toggle Switch            |    | Solenoid              |  |
| Push button Switch (NO)  |     | Control Relay (CR)    |  |
| Push button Switch (NC)  |     | Motor / Motor starter |  |
| Limit Switch (NO)        |    | Lamp                  |  |
| Limit Switch (NC)        |    |                       |   |
| Liquid Level Switch (NO) |   |                       |   |
| Liquid Level Switch (NC) |  |                       |   |
| Relay Contact (NO)       |   |                       |   |
| Relay Contact (NC)       |   |                       |   |

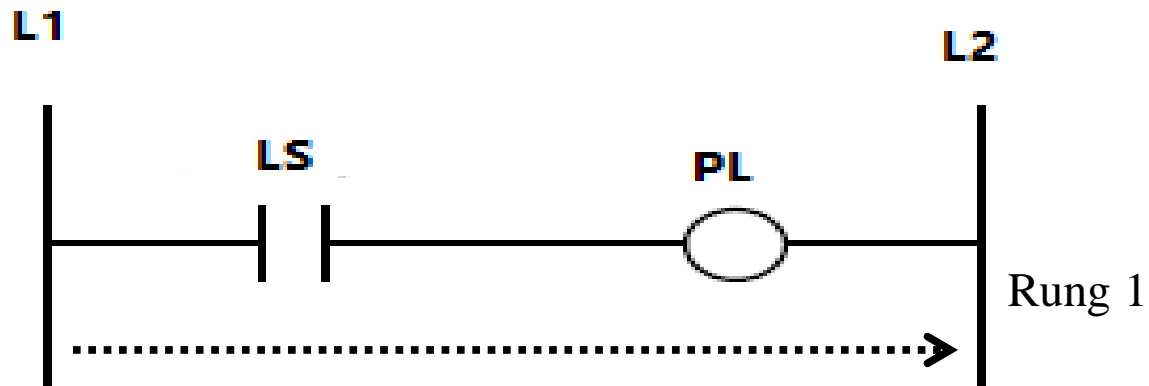
## (2) PLC Ladder Diagram (Ladder diagram)

- Ladder diagram is a graphical programming method shows how to control outputs and perform functional operations based on input conditions.
- Normally open (NO) or normally closed (NC) contacts are used for inputs while coils are used for outputs.
- The contact symbol is the same for any inputs switches (toggle, push button, limit, liquid level, relay contact).
- The coil symbol is the same for any outputs (Solenoid, Lamp, Motor, Control relay).
- The PLC power supply will be the voltage between the two vertical lines (rails or bars), labeled **L1** and **L2**. In general, L1 represents the supply terminal and L2 represents the common (neutral) terminal.
- Relay logic diagrams use rungs (one or more) to accomplish the control of outputs based on input conditions.
- power flows through any rung from left to right such that there exist a continuous path (**logic continuity = rung is true**) through this rung.

**EX1:**



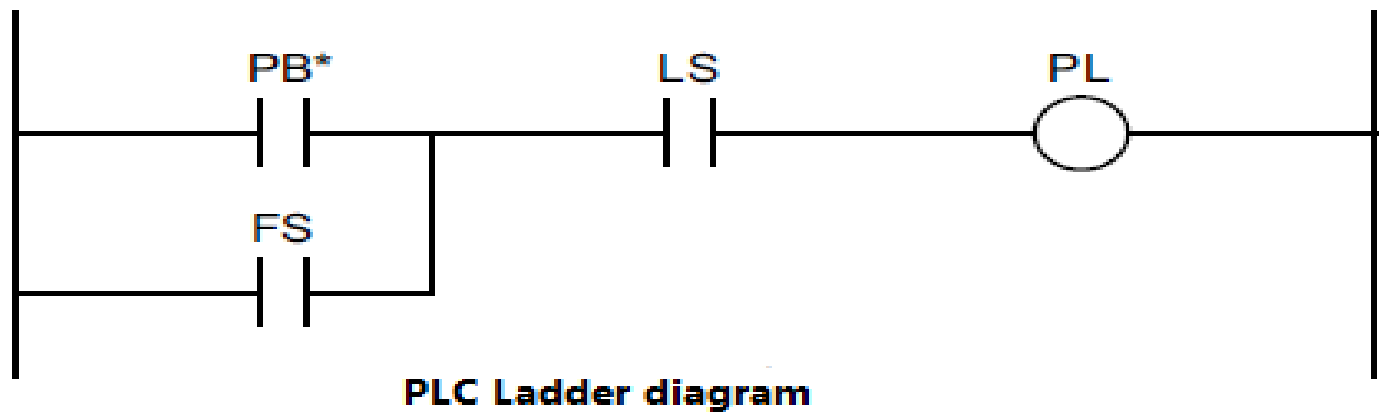
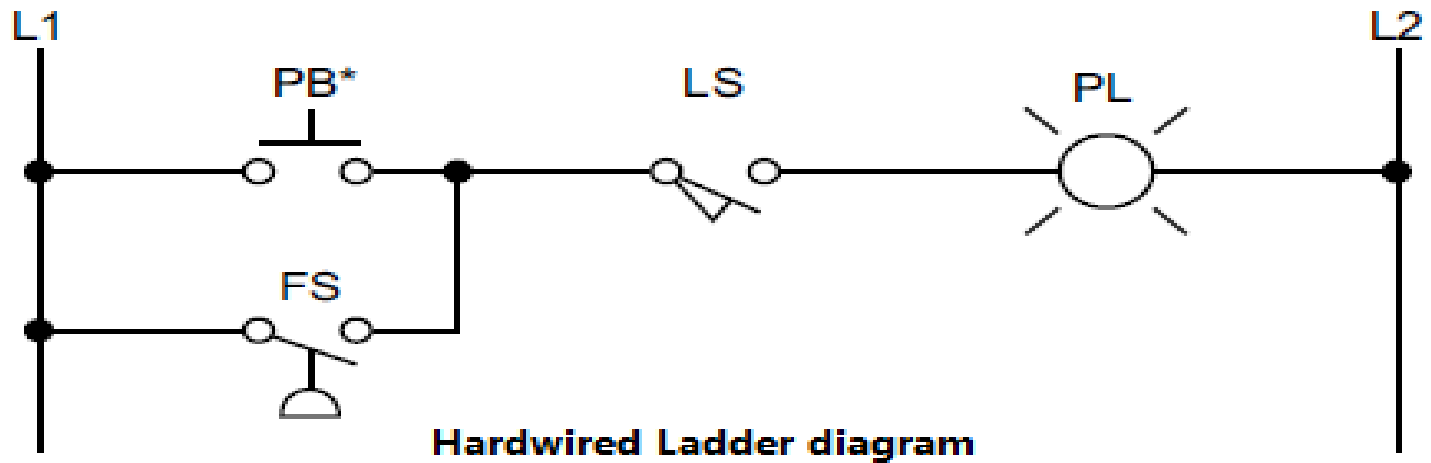
**Relay Logic Ladder Diagram**



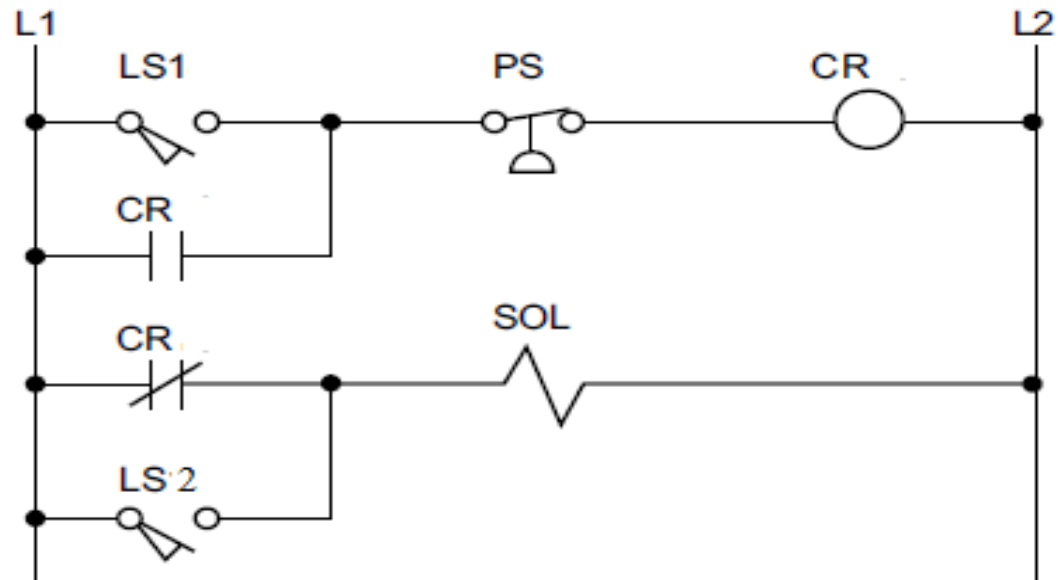
A continuous path is required in a rung to flow power from left to right (rung is true)

**PLC Ladder Diagram**

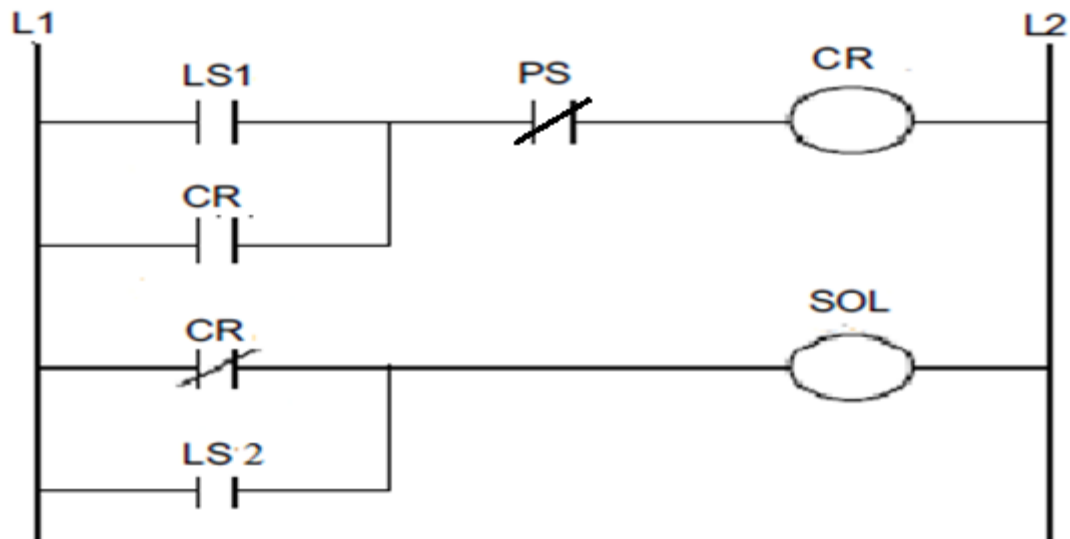
## EX2:



**EX3:**

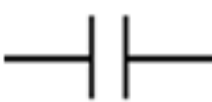
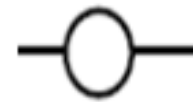



**Relay Logic Ladder Diagram**



**PLC Ladder Diagram**

# Symbols used in Ladder Diagram

| Inputs                   |   | Outputs               |   |
|--------------------------|---|-----------------------|---|
| The input device         | Symbol  | The output device     | Symbol  |
| Toggle Switch (NO)       |    | Solenoid              |  |
| Push button Switch (NO)  |   | Control Relay (CR)    |   |
| Limit Switch (NO)        |   | Motor / Motor starter |   |
| Liquid Level Switch (NO) |   | Lamp                  |   |
| Relay Contact (NO)       |   |                       |   |
| Toggle Switch (NC)       |  |                       |   |
| Push button Switch (NC)  |   |                       |   |
| Limit Switch (NC)        |   |                       |   |
| Liquid Level Switch (NC) |   |                       |   |
| Relay Contact (NC)       |   |                       |   |

# **Guidelines For Using Symbols In PLC Ladder Diagram**

# Guidelines For Using Symbols In PLC Ladder Diagram

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## 1) Normally open contact:

When evaluated by the program, this symbol is **examined for a 1 to close the contact**; therefore, the signal referenced by the symbol must be ON, CLOSED, activated, high, .... etc. (it is called **examine-ON instruction**)

## 2) Normally closed contact:

When evaluated by the program, this symbol is **examined for a 0 to keep the contact closed**; thus, the signal referenced by the symbol must be OFF, OPEN, deactivated, low, ..... etc. (it is called **examine-OFF instruction**)



### 3) Output:

An output on a given rung will be energized if any left-to right path has all contacts closed (continuity path), with the exception of power flow going in reverse before continuing to the right. **An output can control either a connected device or an internal output used exclusively within the program. An internal output does not control a field device. Rather, it provides interlocking functions within the PLC.**

### 4) Input:

This contact symbol can represent input signals sent from connected inputs, contacts from internal outputs, or contacts from connected outputs.



## 5) **Contact addresses:**

Each program symbol is referenced by an address. If the symbol references a connected input/output device, then the address is determined by the point where the input/output device is connected.

## 6) **Repeated use of contacts:**

A given input, output, or internal output can be used throughout the program as many times as required.

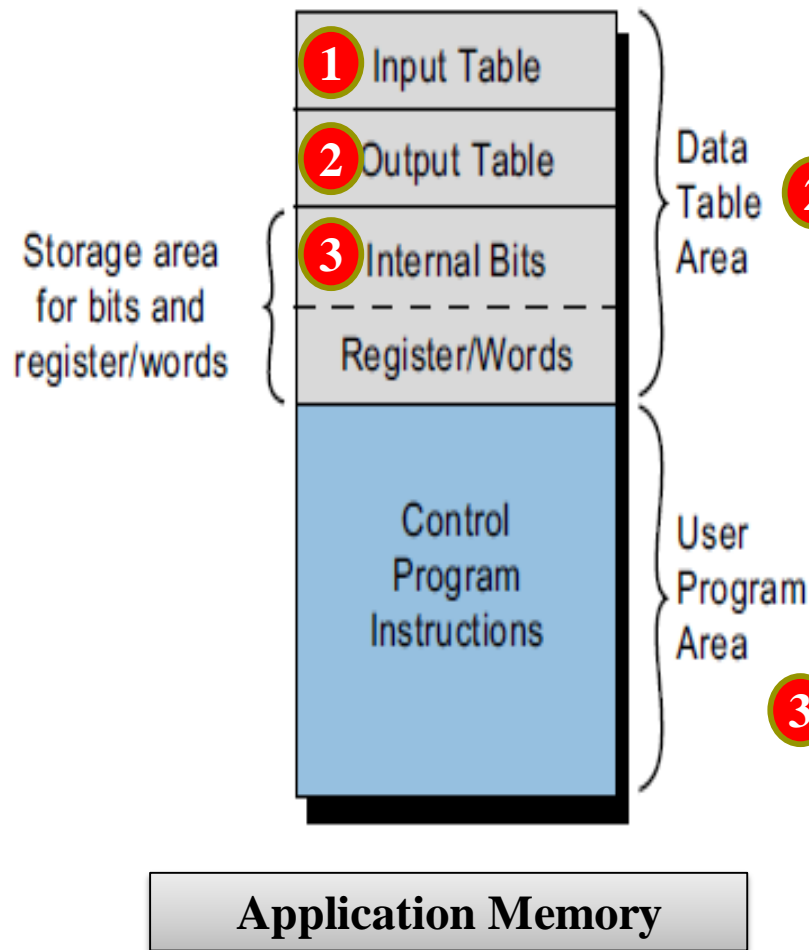
## 7) **Logic format:**

Contacts can be programmed in series or in parallel, depending on the output control logic required. The number of series contacts or parallel branches allowed in a rung depends on the PLC.

# Memory

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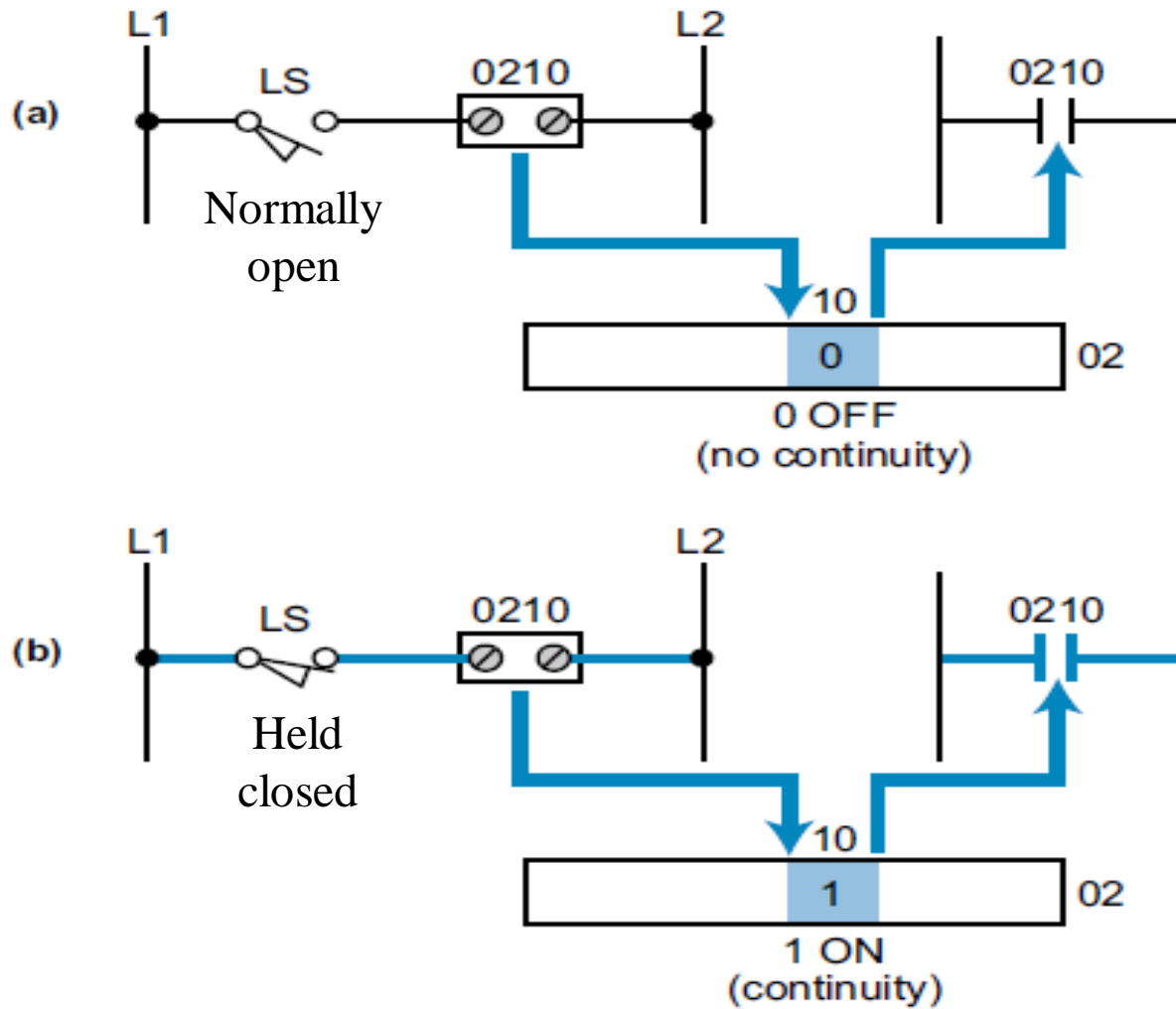
- The total memory system in a PLC is actually composed of two different memories:
  - 1) Executive Memory (System Memory)**
  - 2) Application Memory (User Memory)**
    - Data table area
    - User program Area



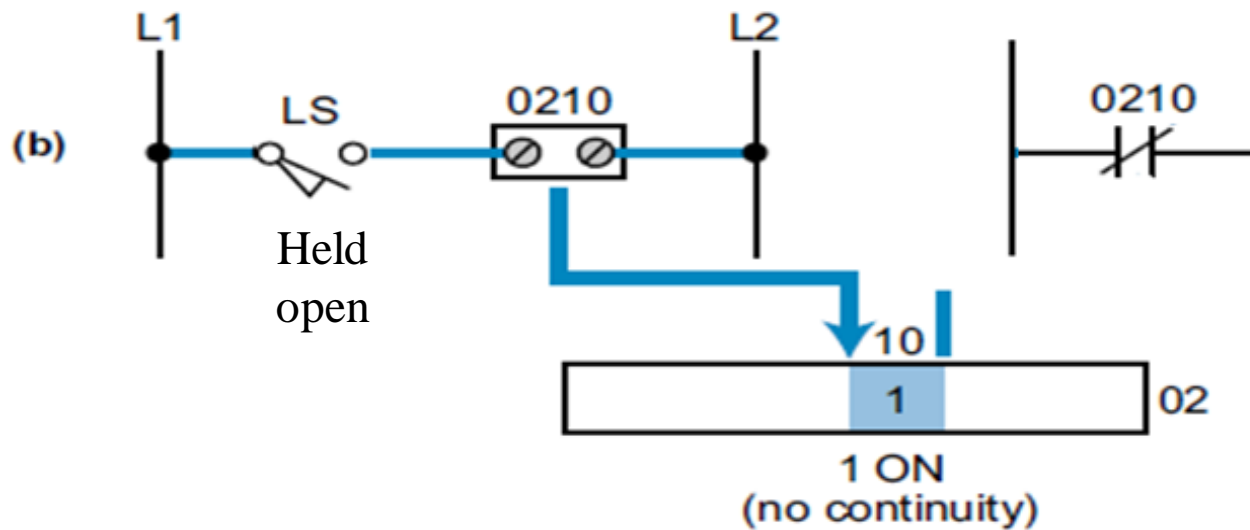
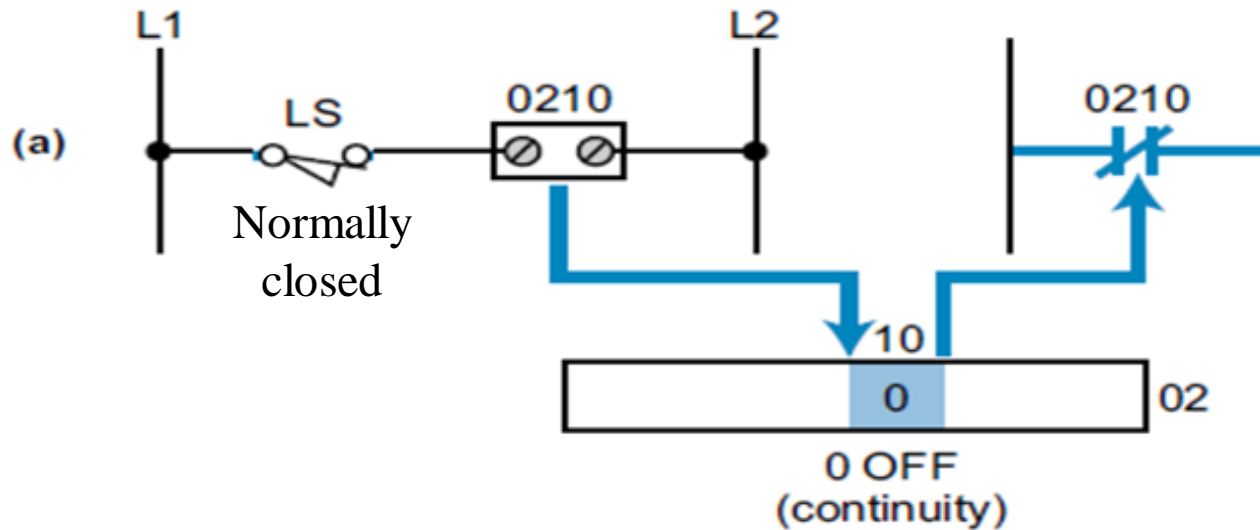
➤ stores the status of digital inputs connected to the PLC's input interface.

➤ Stores the status of control actions of digital output devices that are connected to the PLC's output interface.

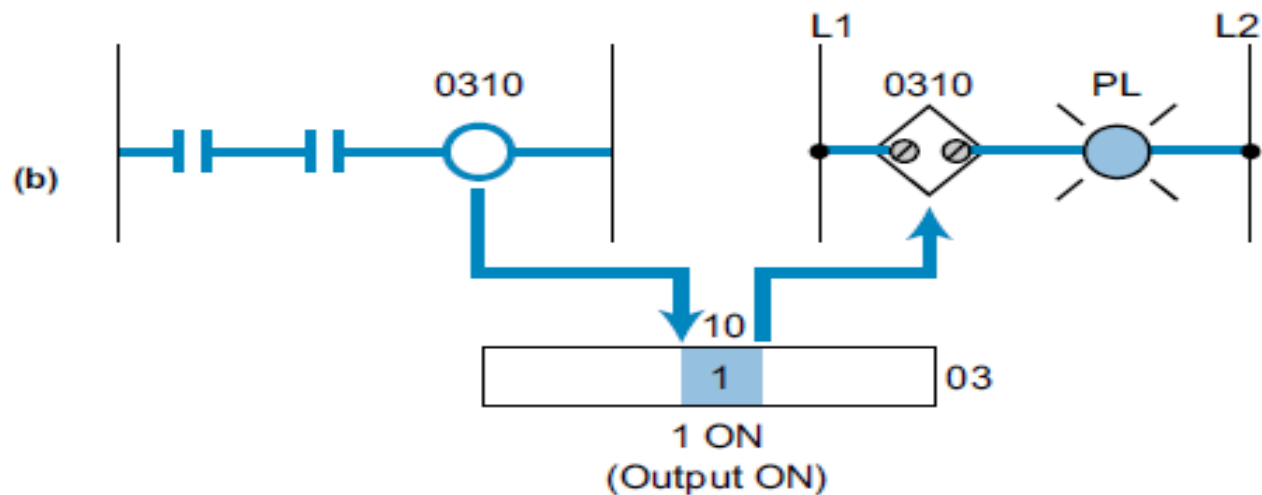
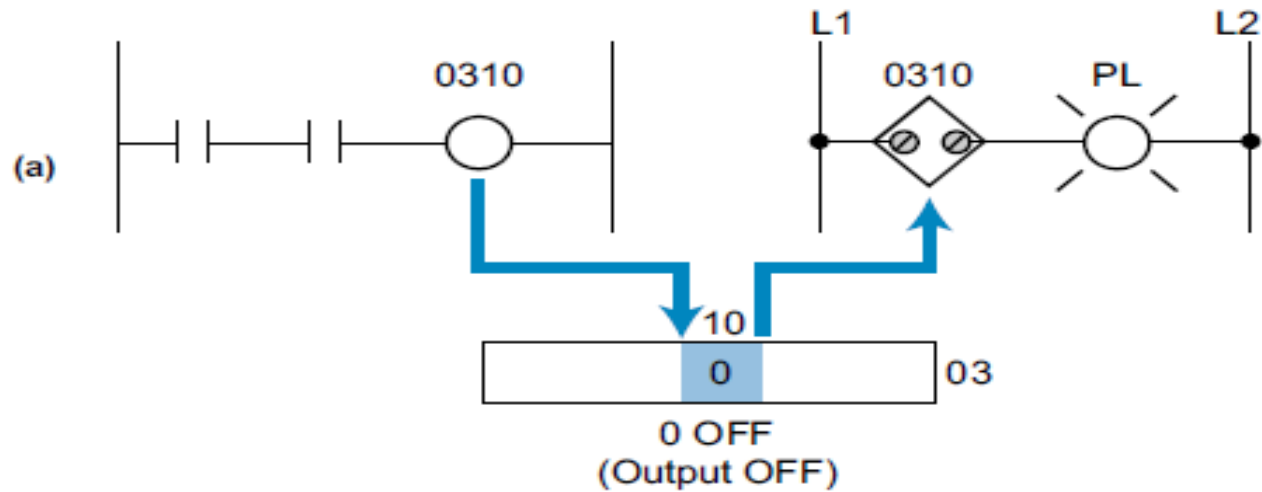
- contains storage bits that are referred to as either internal outputs, internal coils, internal (control relays), or internals.
- These internals provide an output, for interlocking purposes, of ladder sequences in the control program.
- Internal outputs do not directly control output devices because they are stored in addresses that do not map the output table and, therefore, any output devices.



(a) NO Contact with a logic 0 reference address  
(b) NO Contact with a logic 1 reference address



(a) NC Contact with a logic 0 reference address  
(b) NC Contact with a logic 1 reference address



- (a) An Output coil with a logic 0 reference address  
 (b) An Output coil with a logic 1 reference address

# **Basic Logic Operations in Ladder Diagram**

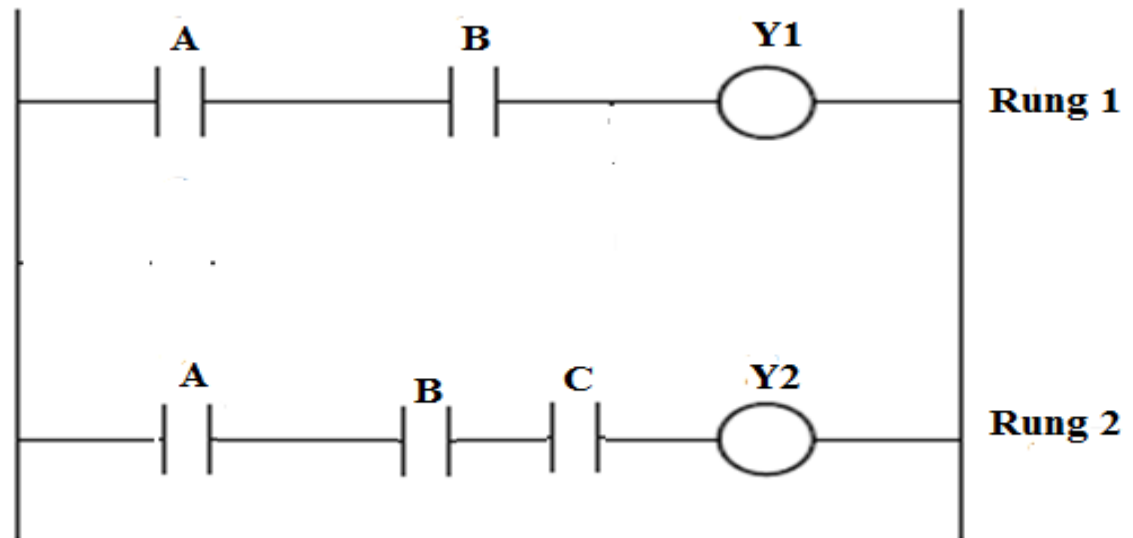


# (1) Logical AND operation in ladder diagram

- The logical AND function is constructed by **series** combinations of digital inputs switches (two or more).

## For Example:

- $Y1 = A \cdot B$
- $Y2 = A \cdot B \cdot C$

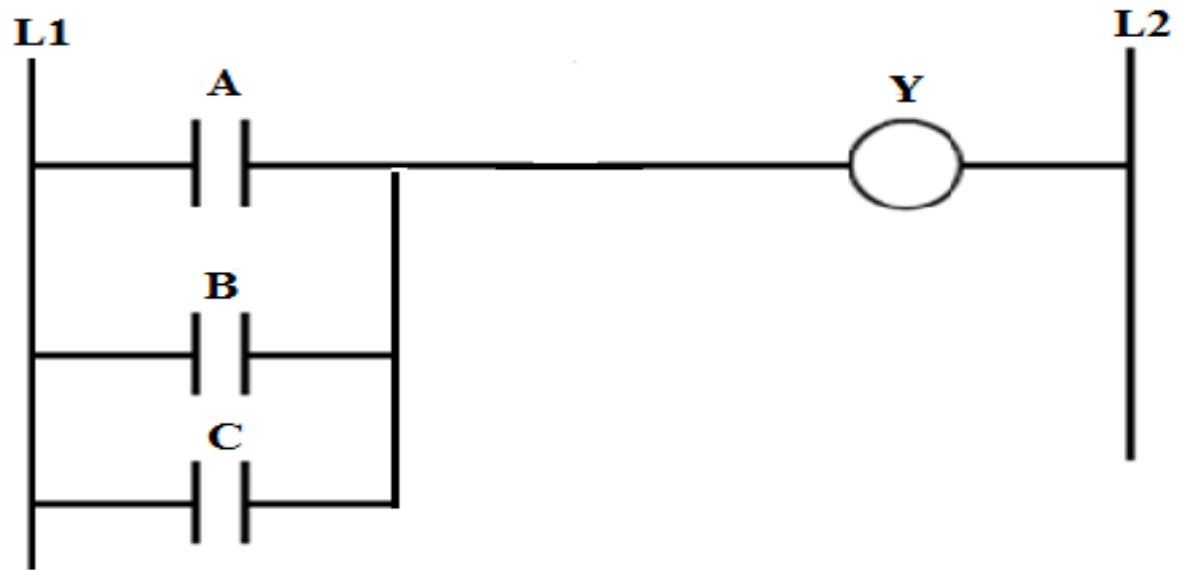


## (2) Logical OR operation in ladder diagram

- The logical OR function is constructed by **parallel** combinations of digital inputs switches (two or more).

### For Example:

- $Y = A + B + C$

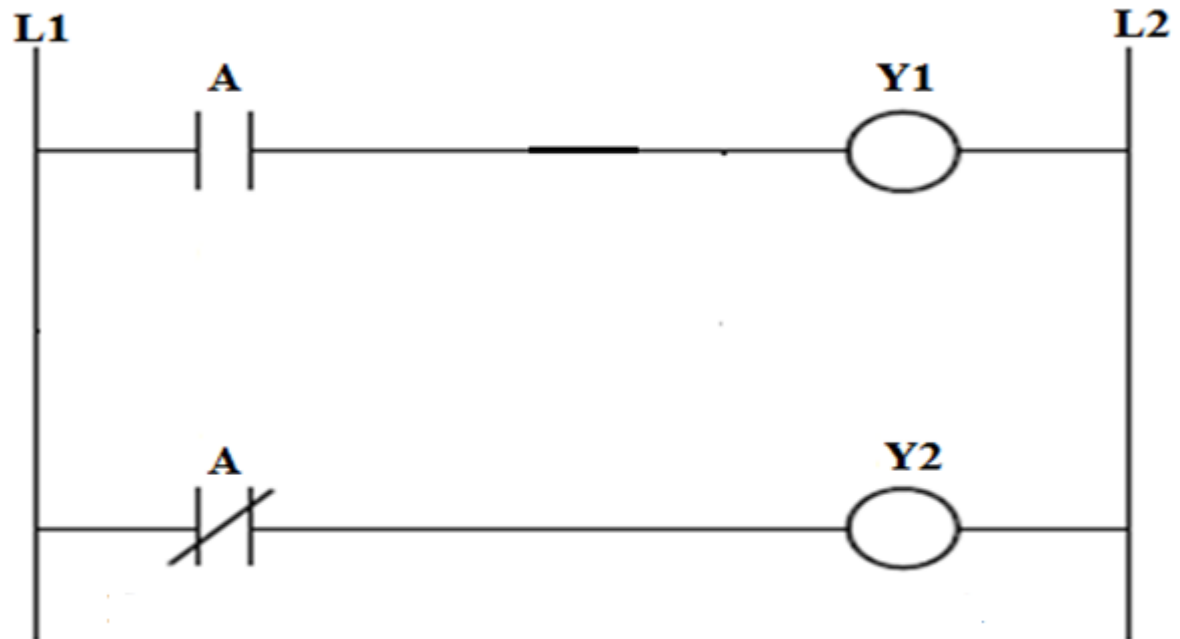


### (3) Logical NOT operation in ladder diagram

- The logical NOT function is constructed by referencing the input signal with a normally closed contact.

#### For Example:

- $Y1 = A$
- $Y2 = A'$



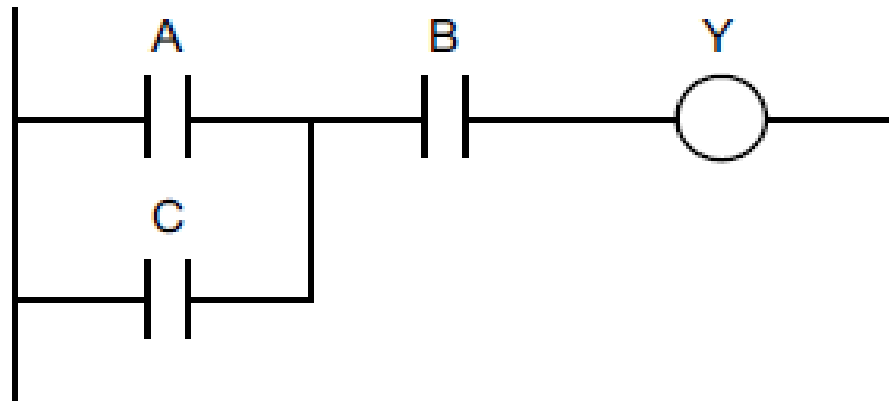
# Example1:

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- Draw the ladder diagram to implement the following logic expression:

$$Y = (A + C) \cdot B$$

Solution



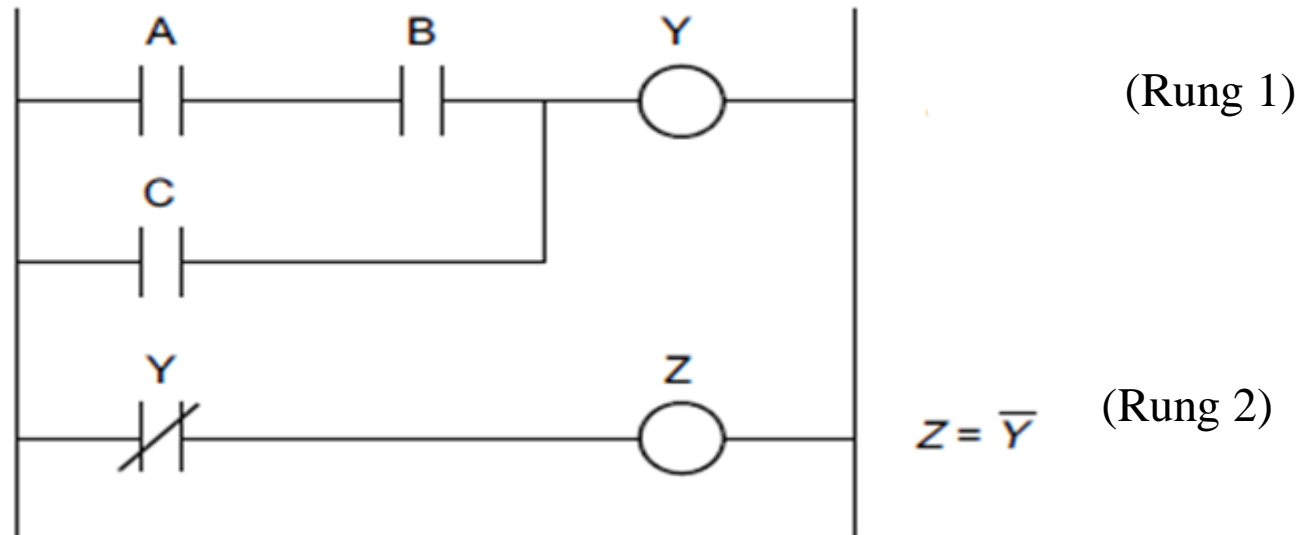
## Example2:

- Draw the ladder diagram to implement the following logic expression:

$$Y = (A.B) + C$$

Solution

$$Z = Y'$$



# Quiz (1)

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- Draw the ladder diagram to implement the following logic expression:

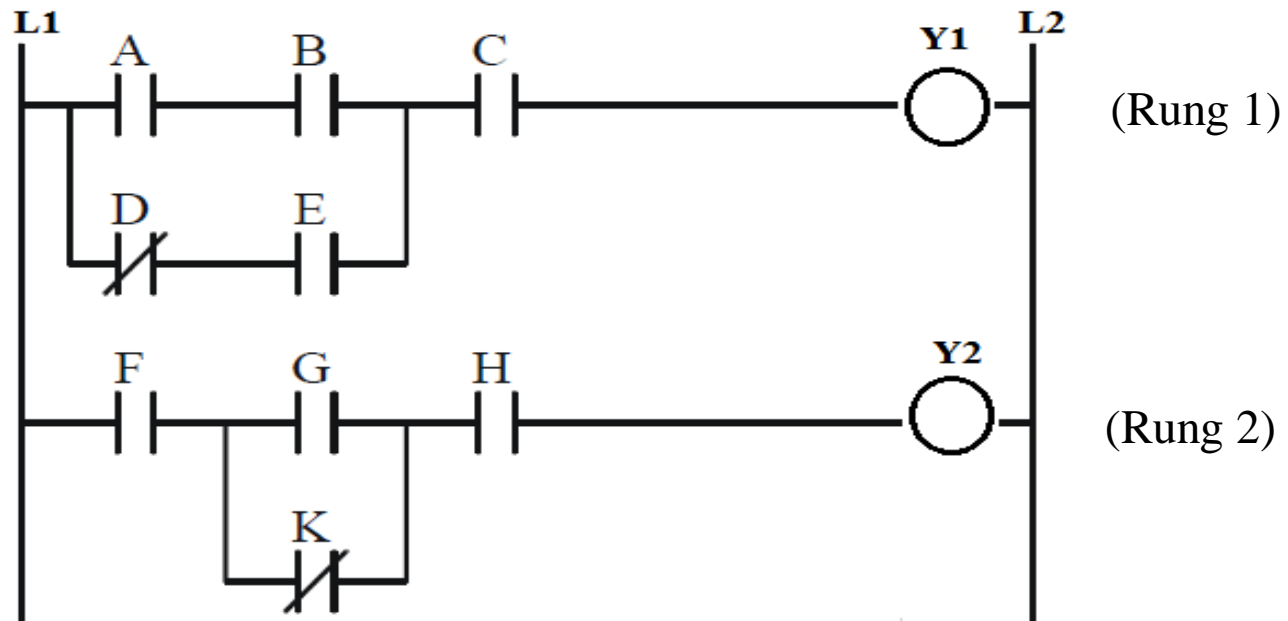
$$Y1 = (A.B + D'.E ).C$$

$$Y2 = F.(G + K').H$$

## Solution

$$Y1 = (A.B + D'.E ).C$$

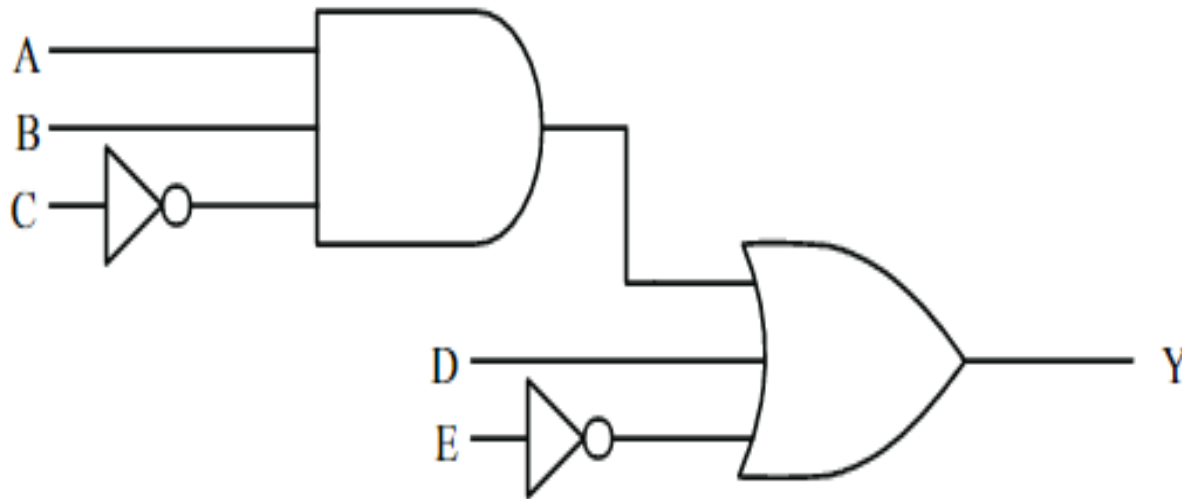
$$Y2 = F.(G + K').H$$



## Quiz (2)

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- Draw the ladder diagram that is equivalent to the following logic circuit:

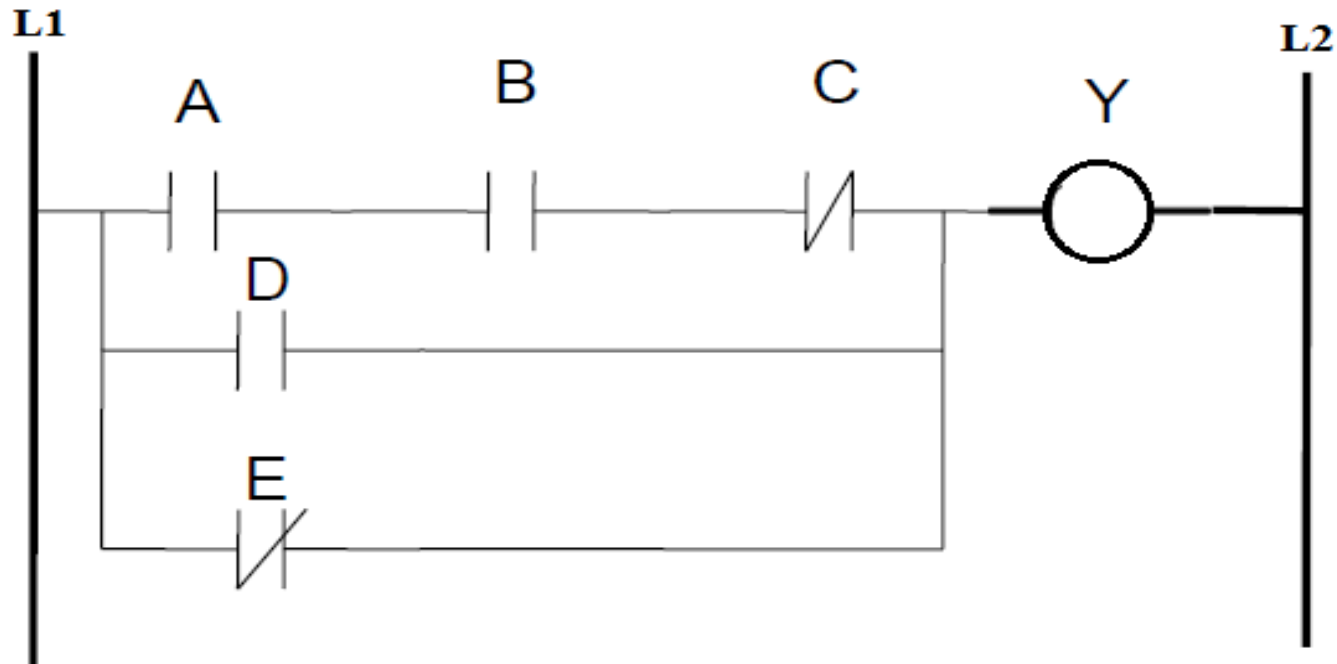




## Solution

The Boolean logic expression is:

$$Y = (A.B.C') + D + E'$$

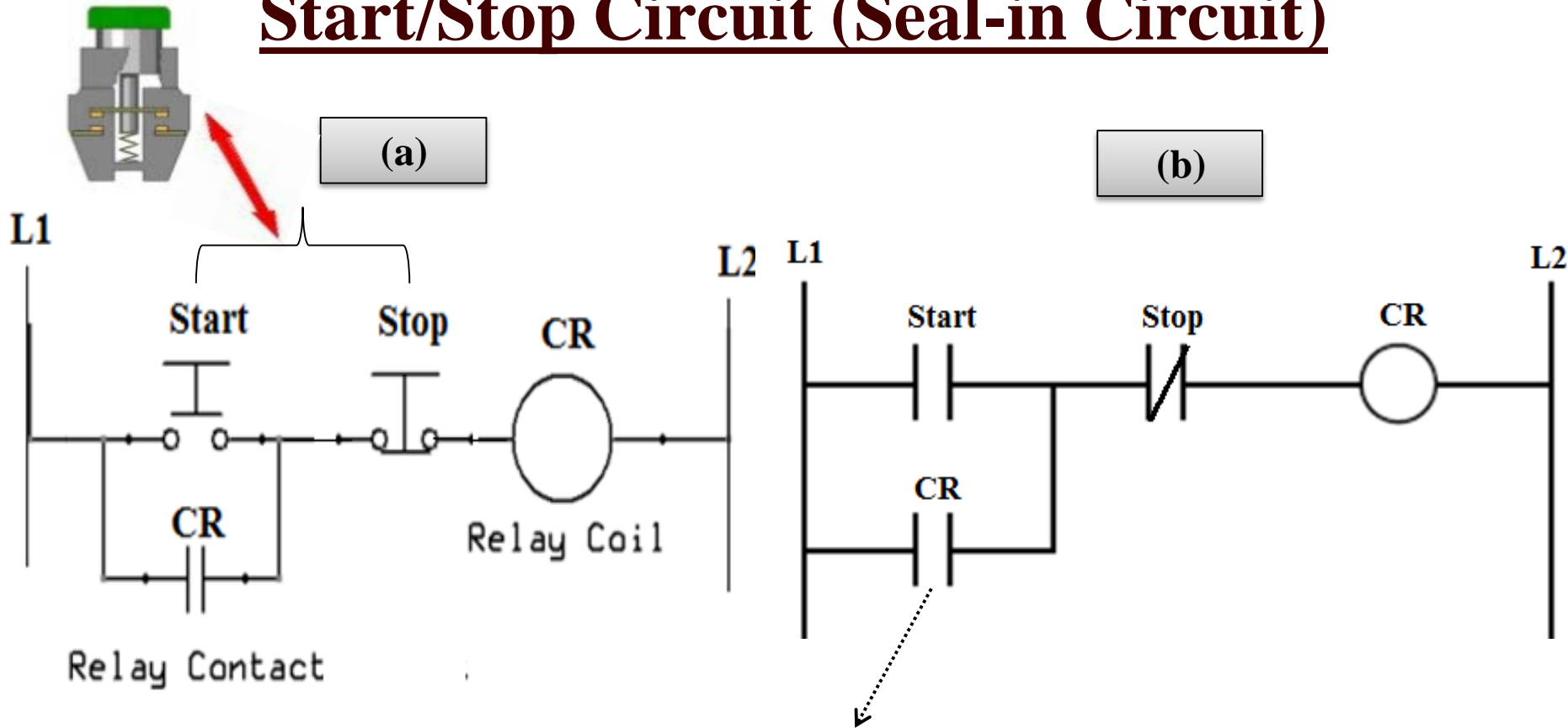


# Start/Stop Circuit (Seal-in Circuit) (Latch / Unlatch Circuit)

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- A seal-in circuit is a method of maintaining current flow after a momentary switch has been pressed and released (push button switch) .
- The **stop button** is normally closed and the **start button** is normally open. There is one relay in the circuit consisting of both **a relay coil and a normally open relay contact** (called **seal-in contact or auxiliary contact**).
- When the start button is pushed it allows current to flow through the relay coil and forces the relay contact to become closed. Once the relay contact is closed there is an alternate path around the start button for current to flow so that when the button returns to its open position the current can flow through the contact and around the switch. When the stop button is pressed it interrupts (disconnects) current flow to the circuit and must be restarted again with the start button.

# Start/Stop Circuit (Seal-in Circuit)



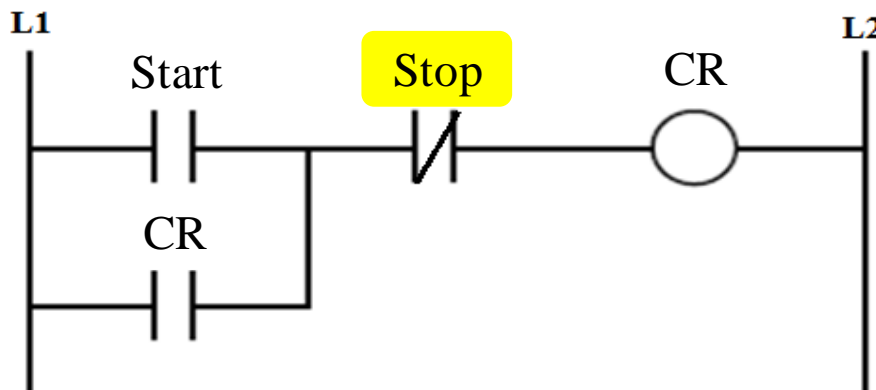
**CR contact** is called auxiliary contact or seal-in contact or latch contact.

**The start/stop circuit:**

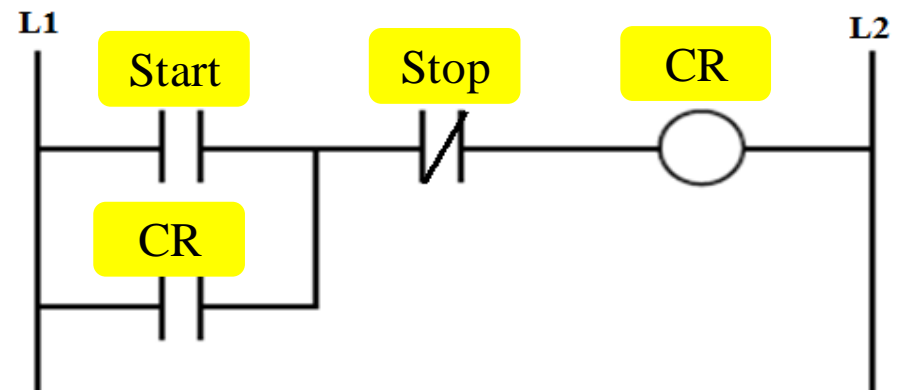
(a) Relay logic diagram

(b) PLC Ladder Diagram

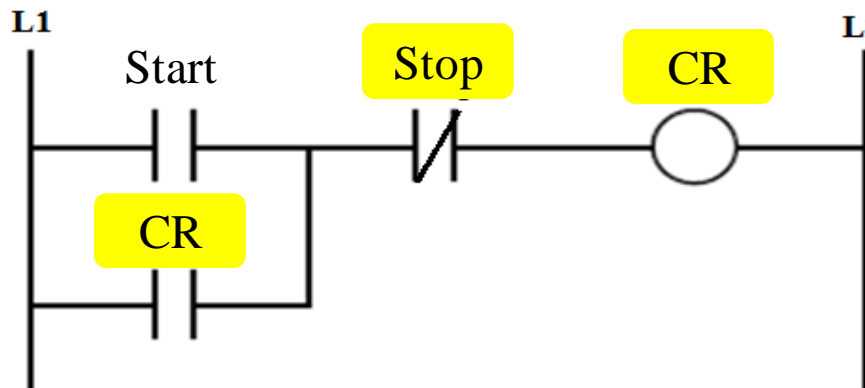
## Start/Stop Circuit Operation



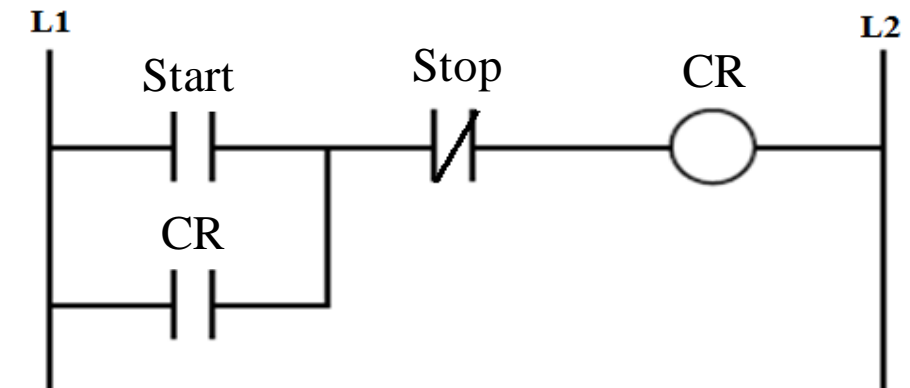
**Initial state**



**Start pushbutton switch pressed**



**Start pushbutton switch released**



**Stop pushbutton switch pressed**

# Interlock circuits

- Interlocks (overlaps) can prohibit output(s) from energizing under a certain condition. Example: M1 should not energize if M2 is energized (and vice versa)

